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(54) **METHOD OF MAKING A TRANSFORMER HAVING A STACKED CORE WITH A CRUCIFORM LEG**

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H01F 3/02 (2006.01)
H01F 7/127 (2006.01)

(52) **U.S. Cl.** **29/602.1**; 29/606; 29/609

(58) **Field of Classification Search** 29/602.1, 29/606, 609; 339/180, 182, 212, 233, 234
See application file for complete search history.

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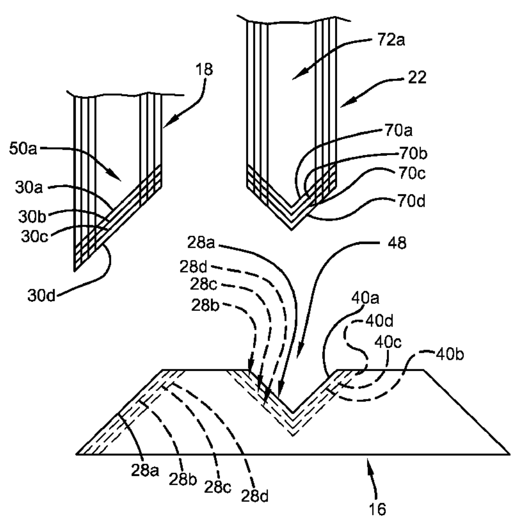
(57) **ABSTRACT**

The present invention is directed to a method of forming a transformer having a stacked core, which includes upper and lower yokes and first and second outer legs. The core also includes one or more inner legs. Each of the upper and lower yokes is formed from a stack of plates and has a rectangular cross-section. Each inner leg is formed from a stack of plates and has a cruciform cross-section. Each of the first and second outer legs is formed from a stack of plates and may have a cruciform cross-section.

11 Claims, 8 Drawing Sheets



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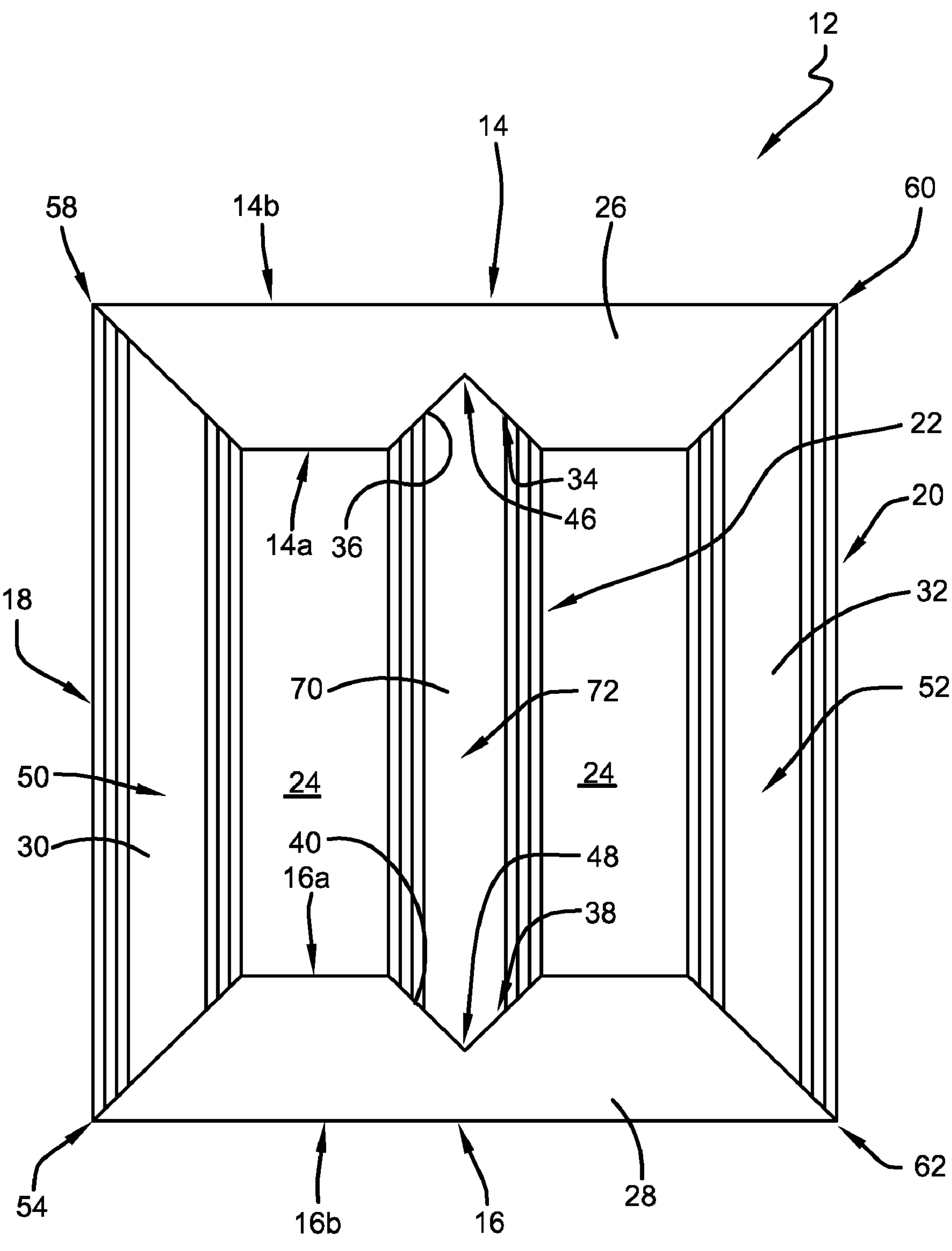
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Fig. 1

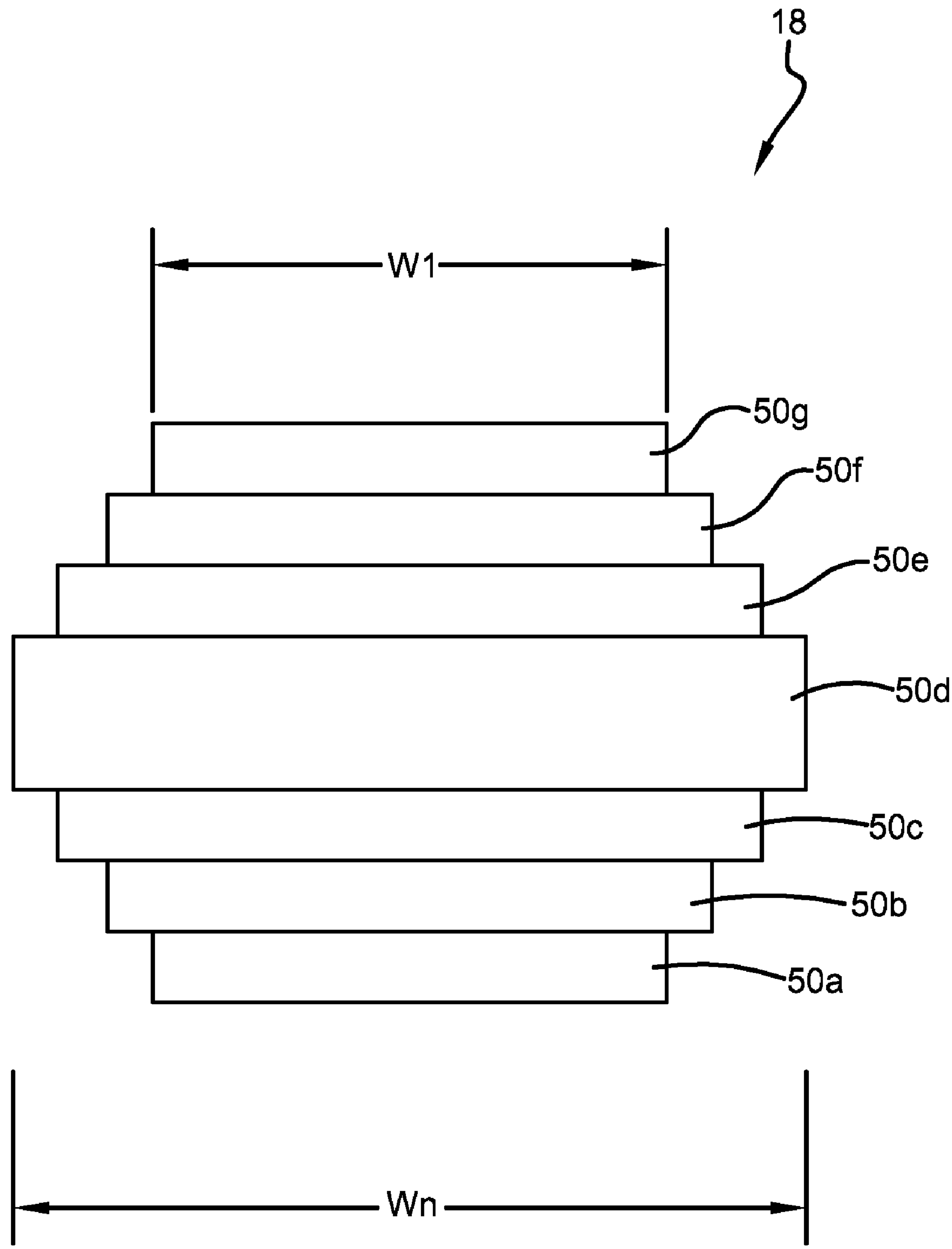

Fig. 2

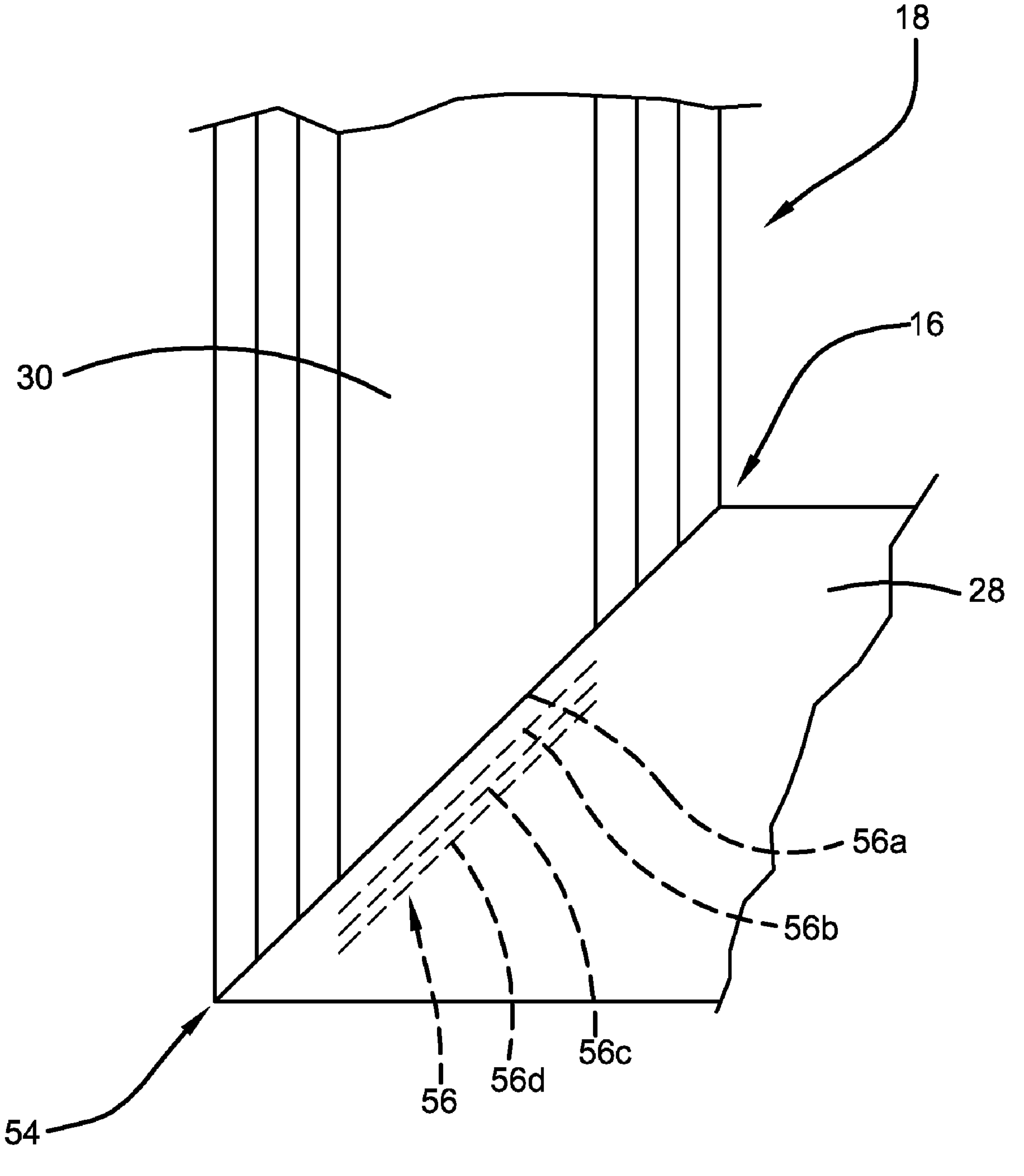

Fig. 3

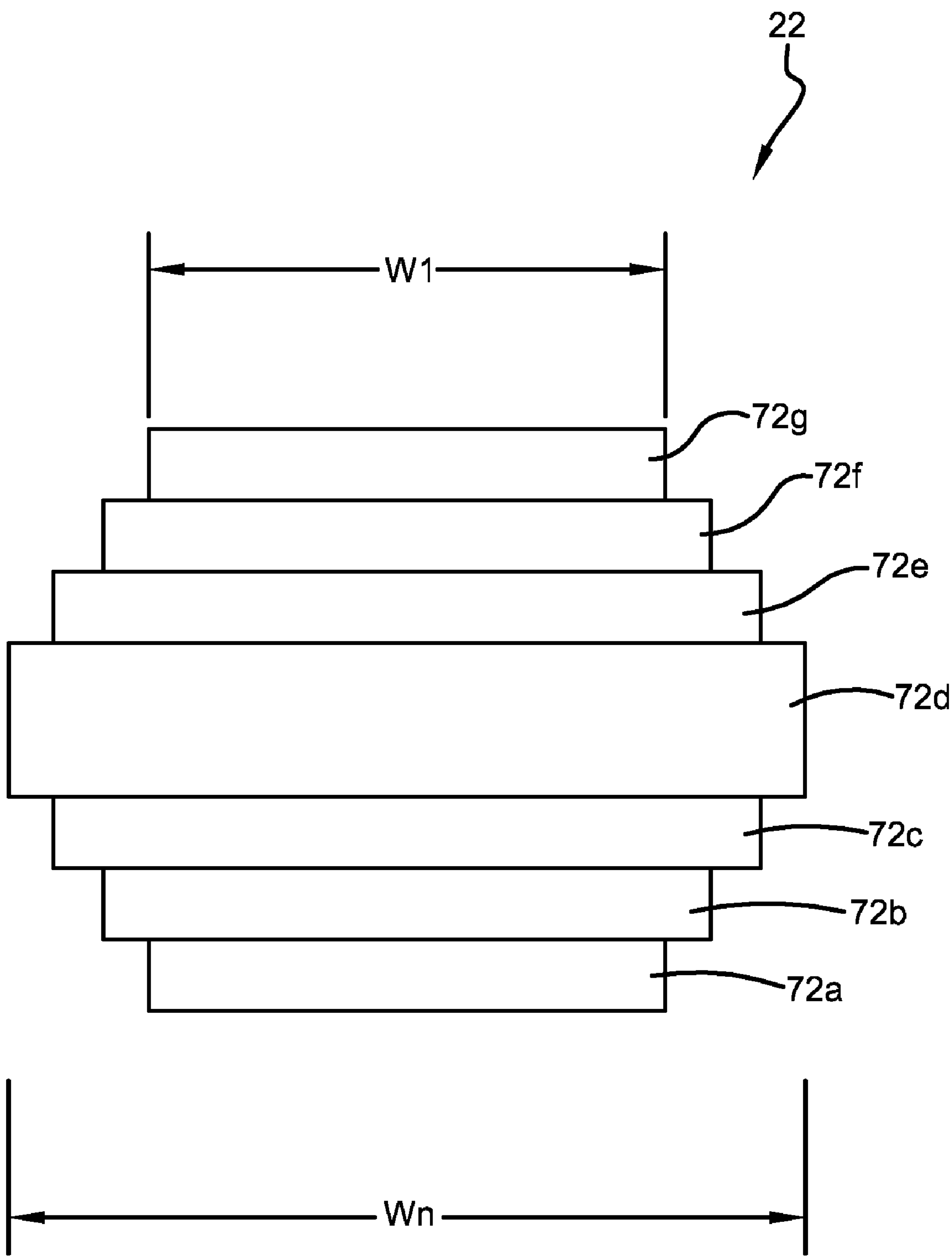

Fig. 4

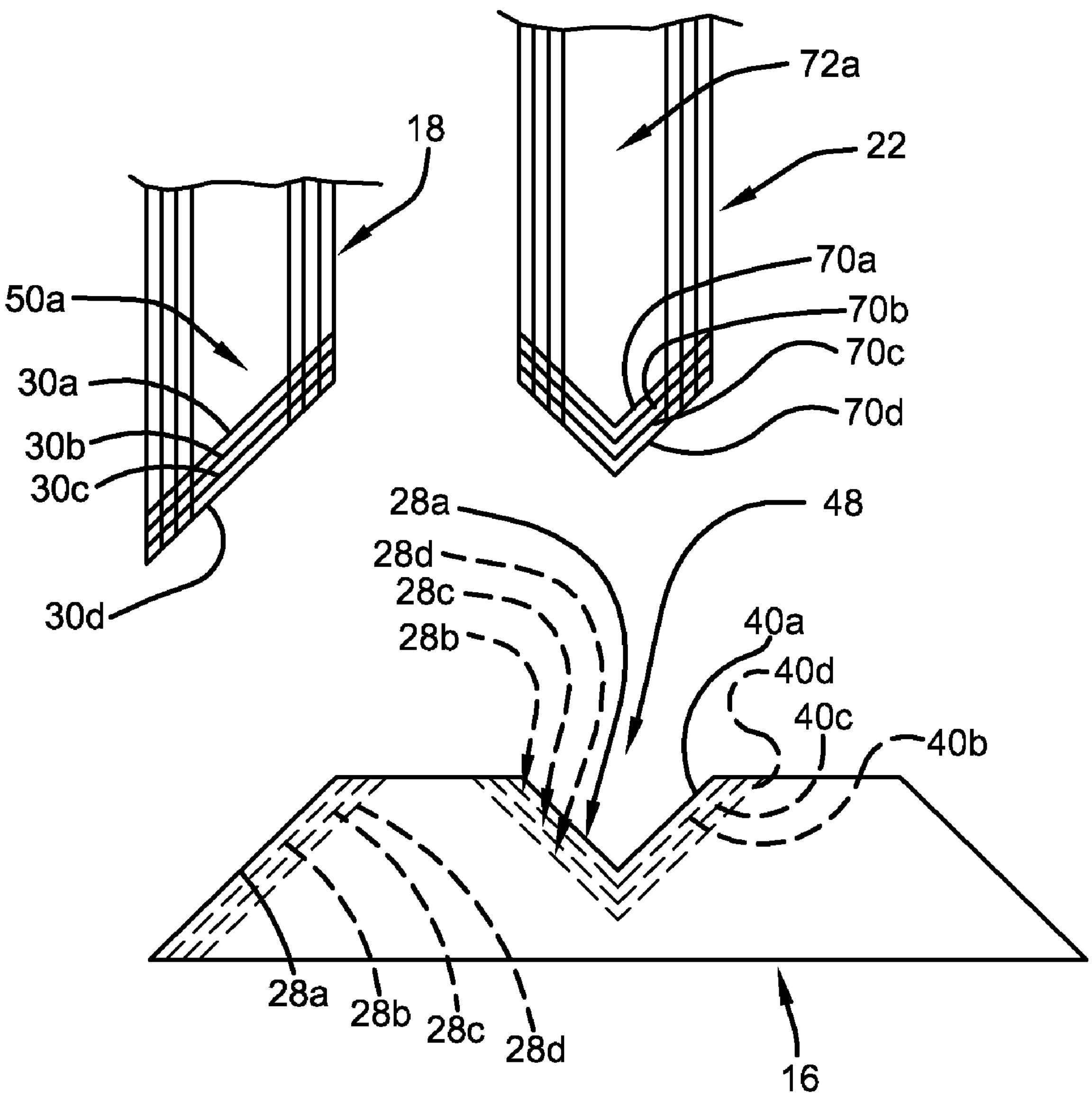
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Fig. 5

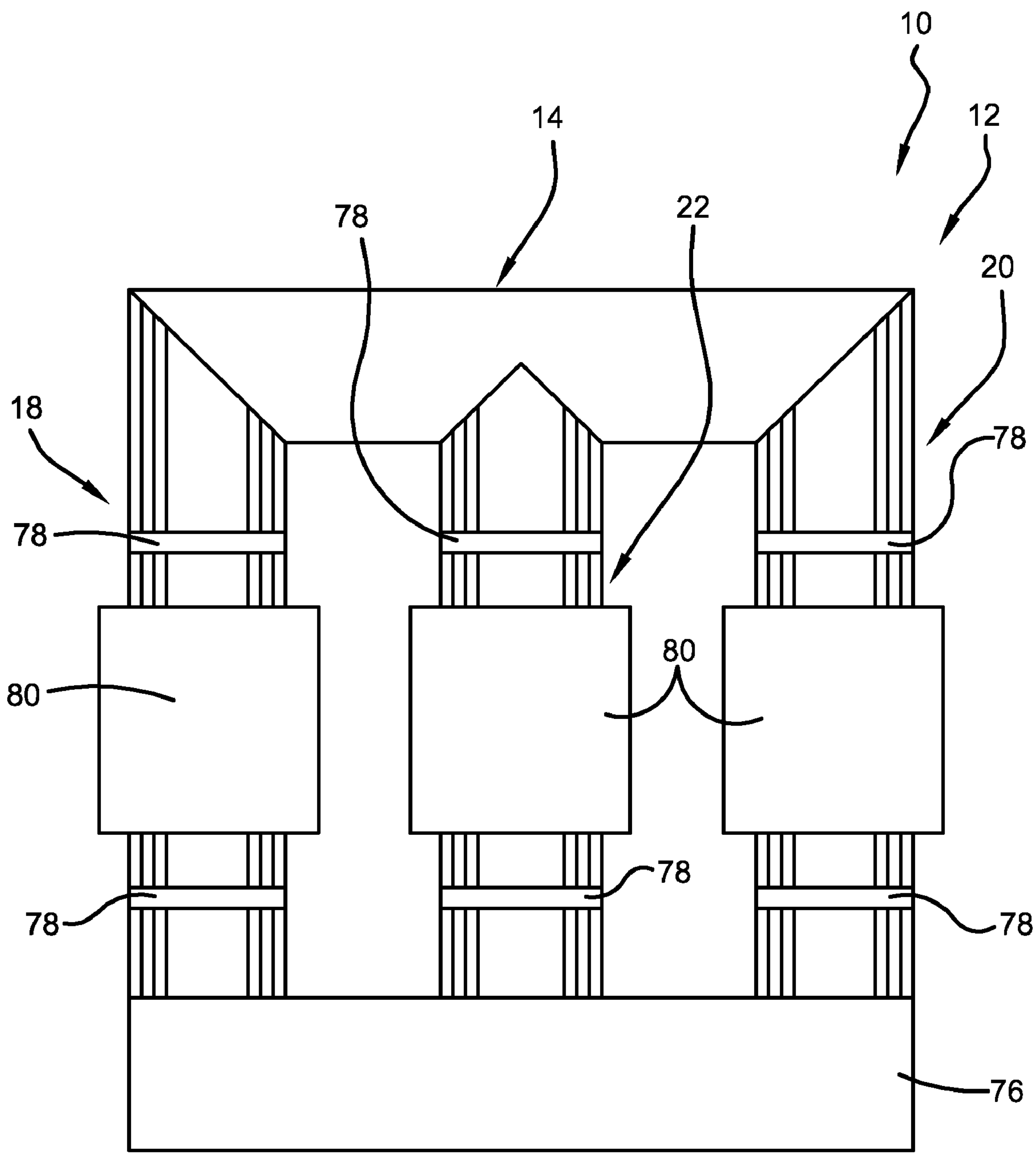

Fig. 6

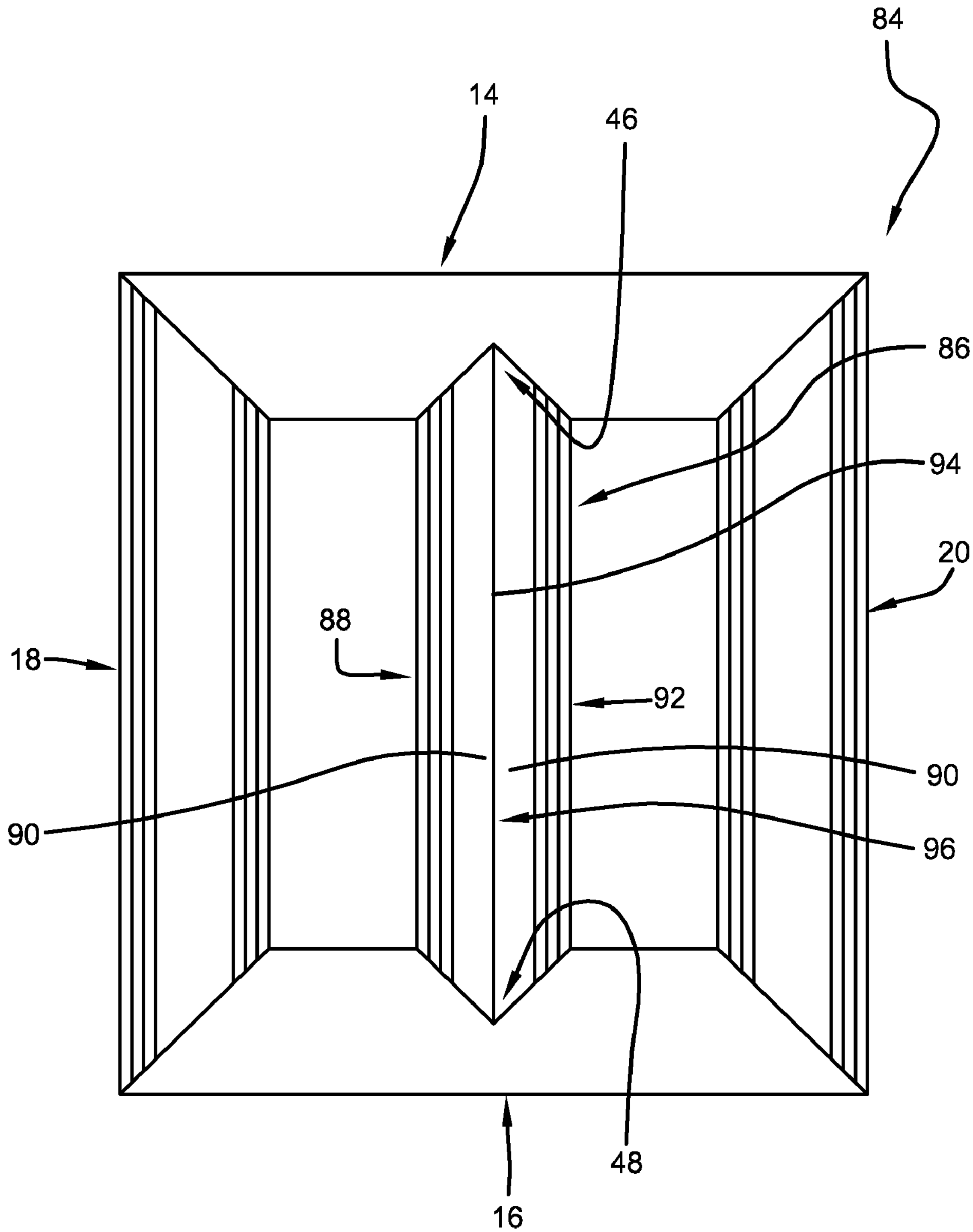

Fig. 7

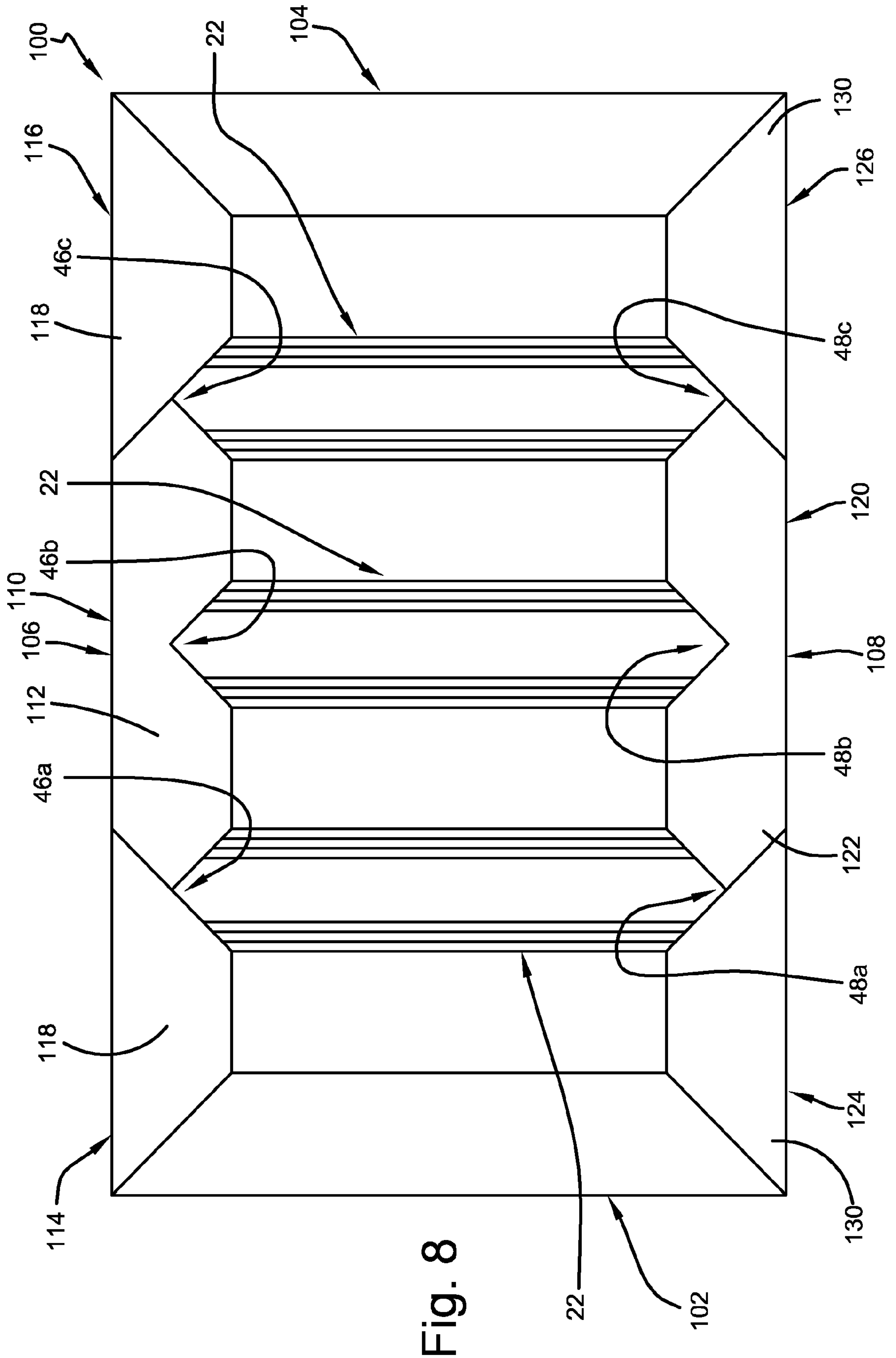
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Fig. 8

METHOD OF MAKING A TRANSFORMER HAVING A STACKED CORE WITH A CRUCIFORM LEG

CROSS CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional application of, and claims priority from, U.S. patent application Ser. No. 11/093,408 filed on Mar. 30, 2005, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The invention relates to transformers and more particularly, to methods of making transformers having a stacked core with a cruciform leg.

BACKGROUND OF THE INVENTION

A stacked transformer core is comprised of thin metallic laminate plates, such as grain oriented silicon steel. This type of material is used because the grain of the steel may be groomed in certain directions to reduce the magnetic field loss. The plates are stacked on top of each other to form a plurality of layers. A stacked core is typically rectangular in shape and can have a rectangular or cruciform cross-section. A cruciform cross-section increases the strength of a stacked core. In addition, a core leg having a cruciform cross-section provides more surface area for supporting a coil. An example of a conventional stacked transformer core having a cruciform cross-section is shown in U.S. Pat. No. 4,283,842 to DeLaurentis et al. The core of the DeLaurentis et al. patent has upper and lower yokes with cruciform cross-sections, as well as legs with cruciform cross-sections.

Although a stacked core having a cruciform cross-section, such as the core of the DeLaurentis et al. patent, provides additional support and strength, such a core is typically more difficult to manufacture and results in more wasted steel. Therefore, it would be desirable to provide a stacked transformer core that has the benefits of a cruciform cross-section, but is simpler to manufacture and reduces the amount of steel that is wasted. The present invention is directed to such a transformer core and a method of making the same.

SUMMARY OF THE INVENTION

In accordance with the present invention, a method of forming a transformer is provided. In accordance with the method, a plurality of outer leg plates, a plurality of inner leg plates and plurality of yokes plates are provided. Not all of the inner leg plates have the same width. Each of the yoke plates has an outer side and an inner side with a notch formed therein. The notch is located inwardly from the outer side. All of the yoke plates have the same width. The outer leg plates, the inner leg plates and the yoke plates are stacked to form a pair of outer legs, a yoke with a groove, and an inner leg having a first end disposed in the groove. The outer legs include the outer leg plates, the inner leg includes the inner leg plates and the yoke included the yoke plates. The groove extends in a stacking direction of the yoke and is formed by the notches of the yoke plates. The inner leg plates are stacked so as to provide the inner leg with a cruciform cross-section and the yoke plates are stacked so as to provide the yoke with a rectangular cross-section. A coil winding is mounted to the inner leg.

Also provided in accordance with the present invention is a method of forming a transformer, wherein a plurality of first leg plates, a plurality of second leg plates, a plurality of first yoke plates and a plurality of second yoke plates are provided. Not all of the second leg plates have the same width, whereas all of the first yoke plates have the same width and all of the second yoke plates have the same width. The first leg plates, the second leg plates and the first yoke plates are stacked to form a core section having first and second legs extending from a first yoke. The first leg includes the first leg plates, the second leg includes the second leg plates and the first yoke includes the first yoke plates. The second leg plates are stacked so as to provide the second leg with a cruciform cross-section and the first yoke plates are stacked so as to provide the first yoke with a rectangular cross-section. A coil winding is mounted to the second leg. The second yoke plates are stacked over the core section to form a second yoke having a rectangular cross-section.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. **1** shows a front elevational view of a transformer core constructed in accordance with a first embodiment of the present invention;

FIG. **2** shows a cross-sectional view of a first outer leg of the transformer core;

FIG. **3** shows a close-up view of a connection between the first outer leg and a lower yoke of the transformer core;

FIG. **4** shows a cross-sectional view of an inner leg of the transformer core;

FIG. **5** shows an enlarged view of a portion of the first outer leg and the inner leg spaced above the lower yoke of the transformer core;

FIG. **6** shows a front elevational view of a transformer with the transformer core;

FIG. **7** shows a front elevational view of a second transformer core embodied in accordance with a second embodiment of the present invention; and

FIG. **8** shows a front elevational view of a third transformer core embodied in accordance with a third embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

It should be noted that in the detailed description that follows, identical components have the same reference numerals, regardless of whether they are shown in different embodiments of the present invention. It should also be noted that in order to clearly and concisely disclose the present invention, the drawings may not necessarily be to scale and certain features of the invention may be shown in somewhat schematic form.

The present invention is directed to a transformer **10** (shown in FIG. **6**), such as a distribution transformer, having a stacked core **12**. The transformer **10** may be an oil-filled transformer, i.e., cooled by oil, or a dry-type transformer, i.e., cooled by air. The construction of the core **12**, however, is especially suitable for use in a dry transformer. Referring now to FIG. **1**, the core **12** has a rectangular shape and generally comprises an upper yoke **14**, a lower yoke **16**, first and second outer legs **18**, **20** and an inner leg **22**. Upper ends of the first and second outer legs **18**, **20** are connected to first and second ends of the upper yoke **14**, respectively, while lower ends of the first and second outer legs **18**, **20** are connected to first and second ends of the lower yoke **16**. The inner leg **22** is disposed midway between the first and second outer legs **18**, **20**. The inner leg **22** has an upper end connected to the upper yoke **14** and a lower end connected to the lower yoke **16**. With this construction, two windows **24** are formed between the inner leg **22** and the first and second outer legs **18**, **20**.

The upper yoke **14** has an inner side **14***a* and an outer side **14***b*, and the lower yoke **16** has an inner side **16***a* and an outer side **16***b*. The upper yoke **14** comprises a stack of plates **26**, while the lower yoke **16** comprises a stack of plates **28**. Both the plates **26** and the plates **28** are arranged in groups. In one exemplary embodiment of the present invention, the groups are groups of seven. Of course, groups of different numbers may be used, such as groups of four, which are used herein for ease of description and illustration. Each of the plates **26**, **28** is composed of grain-oriented silicon steel and has a thickness in a range of from about 7 mils to about 14 mils, with the particular thickness being selected based on the application of the transformer **10**. The plates **26**, **28** each have a unitary construction and are trapezoidal in shape. In each of the plates **26**, **28**, opposing ends of the plate **26**, **28** are mitered at oppositely-directed angles of about 45°, thereby providing the plate **26**, **28** with major and minor sides. The plates **26** have the same width to provide the upper yoke **14** with a rectangular cross-section and the plates **28** have the same width to provide the lower yoke **16** with a rectangular cross-section. However, the lengths of the plates **26** are not all the same and the lengths of the plates **28** are not all the same. More specifically, the lengths within each group of plates **26** are different and the lengths within each group of plates **28** are different. The pattern of different lengths is the same for each group of plates **26** and the pattern of different lengths is the same for each group of plates **28**. The difference in lengths within each group permits the formation of multi-step lap joints with plates **30**, **32** of the first and second outer legs **18**, **20** as will be described more fully below.

A V-shaped upper notch **34** is formed in each of the plates **26** of the upper yoke **14** by an upper interior edge **36** and a V-shaped lower notch **38** is formed in each of the plates **28** of the lower yoke **16** by a lower interior edge **40**. The upper interior edges **36** in adjacent plates **26** of the upper yoke **14** have different depths for forming vertical lap joints with upper ends of inner leg plates **70** of the inner leg **22**, as will be described more fully below. Similarly, the lower interior edges **40** in adjacent plates **28** of the lower yoke **16** have different depths for forming vertical lap joints with lower ends of the inner leg plates **70** of the inner leg **22**, as will be described more fully below. The upper notches **34** form an upper groove **46** in the upper yoke **14**, while the lower notches **38** form a lower groove **48** in the lower yoke **14**. The upper groove **46** is located inwardly from the outer side **14***b*, and the lower groove **48** is located inwardly from the outer side **16***b*. The upper and lower grooves **46**, **48** extend in the stacking directions of the upper and lower yokes **14**, **16**, respectively.

The first outer leg **18** comprises a stack of the plates **30**, while the second outer leg **20** comprises a stack of the plates **32**. The plates **30**, **32** have varying widths so as to provide the first and second outer legs **18**, **20** with cruciform cross-sections. More specifically, the plates **30** are arranged in sections **50** of different widths and the plates **32** are arranged in sections **52** of different widths. In each section **50**, the plates **30** have the same width and in each section **52**, the plates **32** have the same width. For example, and with reference now to FIG. **2**, the first outer leg **18** has sections **50***a,b,c,d,e,f,g* of the plates **30** that in a forward to rearward direction, first successively increase in width and, then after the midpoint, successively decrease in width. The sections **50***a-g* each comprise one or more groups of plates **30**. Thus, the outermost plates **30** in sections **50***a* and **50***g* each have a width W1, which is the smallest of the widths of the plates **30**, and the plates **30** in the middle section **50***d* each have a width Wn, which is the largest of the widths of the plates **30**. The thickness of the sections **50***a-g* in the stacking direction may vary. For example, as shown, the center section **50***d* may be substantially thicker than the other sections **50***a,b,c,e,f,g*. Although not shown, it should be appreciated that the sections **52** of the second outer leg **20** have the same arrangement as the sections **50** of the first outer leg **18**.

Within each section **50**, **52**, the plates **30**, **32** are arranged in groups of the same number as the plates **26**, **28**. Each of the plates **30**, **32** is composed of grain-oriented silicon steel and has a thickness in a range of from about 7 mils to about 14 mils, with the particular thickness being selected based on the application of the transformer. The plates **30**, **32** each have a unitary construction and are trapezoidal in shape. In each of the plates **30**, **32**, opposing ends of the plate **30**, **32** are mitered at oppositely-directed angles of about **450**, thereby providing the plate **30**, **32** with major and minor side edges. The lengths of the plates **30** are not all the same and the lengths of the plates **32** are not all the same. More specifically, the lengths within each group of plates **30** are different and the lengths within each group of plates **32** are different. The pattern of different lengths is the same for each group of plates **30** and the pattern of different lengths is the same for each group of plates **32**. The difference in lengths within each group permits the formation of the multi-step joints with the plates **28** of the first and second outer legs **18**, **20**, as will be described more fully below.

Referring now to FIG. **3** there is shown an enlarged view of the connection (represented by reference number **54**) between the lower end of the first outer leg **18** and the first end of the lower yoke **16**. The ends of the plates **30** form multi-step lap joints **56** with the ends of the plates **28** of the lower yoke **16**. For example, and with reference now also to FIG. **5**, first through fourth plates **30***a-d* of the section **50***a* of the first outer leg **18** form joints **56***a-d* with first through fourth plates **28***a-d* of the lower yoke **16**. Since the plates **30***a-d* in the first section **50***a* are narrower than the plates **28***a-d*, the joints **56***a-d* do not extend the entire length of the mitered ends of the plates **28***a-d*, as is shown. The first through fourth plates **30***a-d* of the first outer leg **18** and the first through fourth plates **28***a-d* of the lower yoke **16** are located successively inward. The first through fourth plates **30***a-d* of the first outer leg **18** have successively longer lengths, whereas the first through fourth plates **28***a-d* of the lower yoke **16** have successively shorter lengths. With this construction, the first plate **28***a* overlaps the joint **56***b* between the second plates **28***b*, **30***b*, the second plate **28***b* overlaps the joint **56***c* between the third plates **28***c*, **30***c* and the third plate **28***c* overlaps the joint **56***d* between the fourth plates **28***d*, **30***d*. Although not shown, this pattern is repeated for the other groups of plates **30** in the first outer leg **18** and the corresponding other groups of plates **28** in the lower yoke **16**. In this manner, the joints **56** that are formed between the plates **28** of the lower yoke **16** and the plates **30** of the first outer leg **18** are multi-step lap joints, with plates **28** of the lower yoke **16** overlapping plates **30** of the first outer leg **18**, respectively.

The other connections (represented by reference numerals **58**, **60**, **62**) between the first and second outer legs **18**, **20** and the upper and lower yokes **14**,**16** are constructed in the same manner as the connection **54** so as to have multi-step lap joints. It should be appreciated, however, that the connections

54, **58**, **60**, **62** may have a different type of construction. For example, instead of the connections **54**, **58**, **60**, **62** having a four step lap joint pattern, the connections **54**, **58**, **60**, **62** may have a seven, or other number step lap joint pattern. In addition, instead of having plates **26**, **28** of the upper and lower yokes **14**,**16** overlapping plates **30**, **32** of the first and second outer legs **18**, **20**, plates **30**, **32** of the first and second outer legs **18**, **20** may overlap plates **26**, **28** of the upper and lower yokes **14**,**16**.

The inner leg **22** comprises a stack of inner leg plates **70**. The inner leg plates **70** have varying widths so as to provide the inner leg **22** with a cruciform cross-section. More specifically, the inner leg plates **70** are arranged in sections **72** of different widths, wherein in each section **72**, the inner leg plates **70** have the same width. This is best illustrated in FIG. **4**, which shows the inner leg **22** having sections **72***a,b,c,d,e,f,g* of the inner leg plates **70** that in a forward to rearward direction, first successively increase in width and, then after the midpoint, successively decrease in width. The sections **72***a-g* each comprise one or more groups of inner leg plates **70**. Thus, the outermost inner leg plates **70** in sections **72***a* and **72***g* each have a width W**1**, which is the smallest of the widths of the inner leg plates **70**, and the inner leg plates **70** in the middle section **72***d* each have a width Wn, which is the largest of the widths of the inner leg plates **70**. As with the first and second outer legs **18**, **20**, the thickness of the sections **72***a-g* in the stacking direction may vary. For example, as shown, the center section **72***d* may be substantially thicker than the other sections **72***a,b,c,e,f,g*.

Within each section **72**, the inner leg plates **70** are arranged in groups of the same number as the plates **26**, **28** (e.g. four). Each of the inner leg plates **70** is composed of grain-oriented silicon steel and has a thickness in a range of from about 7 mils to about 14 mils, with the particular thickness being selected based on the application of the transformer **10**. The inner leg plates **70** each have a unitary construction and include upper and lower pointed or tined ends, wherein each of the upper and lower tined ends is formed by a pair of miter cuts of about 45° each. The inner leg plates **70** may all have the same length if the joints are offset by vertically shifting the inner leg plates **70**. Alternately, the inner leg plates **70** may have a plurality of different lengths if the joints are offset by the different lengths of adjacent inner leg plates **70**.

Referring now to FIG. **5**, when the lower end of the inner leg **22** is disposed in the lower groove **48**, the ends of first, second, third and fourth inner leg plates **70***a, b, c, d* of section **72***a* abut (form joints with) the lower interior edges **40***a,b,c,d* of the first, second, third and fourth plates **28***a, b, c, d* of the lower yoke **16**, respectively. The first through fourth inner leg plates **70***a-d* are vertically offset such that lower ends thereof are located successively farther downward. In order to accommodate these differences in length, the lower interior edges **40***a,b,c,d* of the plates **28***a-d* are cut successively deeper. With this construction, the first plate **28***a* overlaps the joint between the second inner leg plate **70***b* and the second plate **28***b*, the second plate **28***b* overlaps the joint between the third inner leg plate **70***c* and the third plate **28***c*, and the third plate **28***c* overlaps the joint between the fourth inner leg plate **70***d* and the fourth plate **28***d*. Although not shown, this pattern is repeated for the other groups of inner leg plates **70** in the inner leg **22** and the corresponding other groups of plates **28** in the lower yoke **16**. In this manner, vertical multi-step lap joints are formed between the plates **28** of the lower yoke **16** and the inner leg plates **70** of the inner leg **22**, with plates **28** of the lower yoke **16** overlapping plates **70** of the inner leg **22**.

Since the lower ends of the first through fourth inner leg plates **70***a-d* of the inner leg **22** are located successively farther downward, upper ends of the first through fourth inner leg plates **70***a,b,c,d* of the inner leg **22** are located successively farther downward. As a result, the upper interior edges **36** (and, thus, the upper notches **34**) of the plates **26** within each group are successively shallower, which is the inverse of the lower yoke **16**. With this construction, vertical multi-step lap joints are formed between the plates **26** of the upper yoke **14** and the inner leg plates **70** of the inner leg **22**, with inner leg plates **70** overlapping plates **26** of the upper yoke **14**.

It should be appreciated that the inner leg plates **70** of the inner leg **22** may be offset differently so as to have plates **26** of the upper yoke **14** overlapping inner leg plates **70** and inner leg plates **70** overlapping plates **28** of the lower yoke **16**. In addition, the inner leg plates **70** may be offset to form a seven or other number step lap joint pattern, instead of the four step lap joint pattern.

In the embodiment where the inner leg plates **70** have different lengths, vertical multi-step lap joints are formed between the plates **26**, **28** of the upper and lower yokes **14**, **16** in a manner similar to that described above, however, the upper interior edges **36** (and thus the upper notches **34**) of the plates **26** of the upper yoke **14** may have the same arrangement as the lower interior edges **40** (and thus the lower notches **38**) of the plates **28** of the lower yoke **16** with regard to depth, because there is no vertical shifting of the inner leg plates **70**.

The method of assembling the core **12** is dependent on the size of the core **12**. If the core **12** is large, such as would be the case if the transformer **10** was greater than 3000 kva, the core **12** is assembled with the lower yoke **16**, the inner leg **22** and the first and second outer legs **18**, **20** initially being disposed horizontally, i.e., the lower yoke **16**, the inner leg **22** and the first and second outer legs **18**, **20** are stacked in a vertical direction. In such a case the core **12** is assembled on a mounting fixture in a plurality of layers. In a first layer, a group of plates **28** is laid on the mounting fixture, with the major side disposed outwardly. Next, a group of plates **30** and a group of plates **32** are laid on the mounting fixture, with their major sides disposed outwardly and their ends abutting the ends of the group of plates **28**, respectively, to form multi-step lap joints. A group of offset inner leg plates **70** are then laid on the mounting fixture, with the tined lower ends of the inner leg plates **70** abutting the lower interior edges **40** of the plates **28**, respectively, to form multi-step vertical lap joints. This laying process is repeated for each layer until a desired stacking configuration is achieved. Once the lower yoke **16**, the inner leg **22** and the first and second outer legs **18**, **20** have been formed, the lower yoke **16** is clamped between a pair of end frames or supports **76** and bands **78** are disposed around the inner leg **22** and the first and second outer legs **18**,**20**, respectively, as shown in FIG. **6**. The partially formed core **12** is then moved to an upright position so that the inner leg **22** and the first and second outer legs **18**,**20** extend vertically. Coil windings **80** are then disposed over the inner leg **22** and the first and second outer legs **18**, **20**, respectively. The upper yoke **14** is then stacked in groups of plates **26** onto the ends of the inner leg **22** and the first and second outer legs **18**, **20**.

If the core **12** is smaller, such as would be the case if the transformer **10** was less than 3000 kva, the core **12** is assembled in a similar manner as described above, except the core **12** is formed while being disposed vertically, i.e., the components of the core **12** are stacked in a horizontal direction.

After the core **12** with the coil windings **80** is fully constructed, the core **12** is enclosed within a housing (not shown). If the transformer **10** is an oil-filled type of transformer, the core **12** is immersed in oil within a compartment in the housing. If the transformer **10** is a dry-type of transformer, the core **12** is not immersed in oil and the housing is provided with louvers to permit air to enter the housing and pass over the core **12**.

Although the assembly of the core **12** set forth above describes three coil windings **80** being mounted to the core **12**, such as occurs when the transformer **10** is a three-phase transformer, it should be appreciated that in another embodiment, a single coil winding **80** may be mounted to the inner leg **22** of the core **12**, such as occurs when the transformer **10** is a single phase transformer.

Referring now to FIG. **7**, there is shown a core **84** embodied in accordance with a second embodiment of the present invention. The core **84** has substantially the same construction, is constructed in substantially the same manner and may be used in a transformer in substantially the same manner as the core **12**, except for the differences set forth below. Instead of having the inner leg **22**, the core **84** has an inner leg **86**, which comprises a first stack **88** of inner leg plates **90** and a second stack **92** of inner leg plates **90**. The first and second stacks **88**, **92** abut each other along a seam **94** that extends in the longitudinal direction of the inner leg **86**. Upper ends of the first and second stacks **88**, **92** are disposed in the upper groove **46** of the upper yoke **14** and lower ends of the first and second stacks **88**, **92** are disposed in the lower groove **48** of the lower yoke **16**. Each of the inner leg plates **90** has a unitary construction and is trapezoidal in shape. In each of the inner leg plates **90**, opposing ends of the inner leg plate **90** are mitered at oppositely-directed angles of about 45°, thereby providing the inner leg plate **90** with major and minor side edges. In each layer of the inner leg **86**, a major side edge of an inner leg plate **90** of the first stack **88** abuts a major side edge of an inner leg plate **90** of the second stack **92**. With this orientation, the two mitered ends of the abutting inner leg plates **90** at each end of the layer cooperate to provide the end of the layer with a pointed or tined configuration.

The inner leg plates **90** have varying widths so as to provide the inner leg **86** with a cruciform cross-section. More specifically, the inner leg plates **90** are arranged in sections **96** of different widths, wherein each section **96** comprises a portion of the first stack **88** and an adjacent portion of the second stack **92**. The inner leg plates **90** in each section **96** have the same width. In each of the first and second stacks **88**, **92**, the major side edges of the inner leg plates **90** are aligned at the seam **94**. The different widths, however, cause the minor sides to be offset, which helps form the cruciform cross-section of the inner leg **86**.

The inner leg plates **90** in each section **96** may be cut from the same roll of metal in the manner described in U.S. Pat. No. 7,199,696, entitled "A TRANSFORMER HAVING A STACKED CORE WITH A SPLIT LEG AND A METHOD OF MAKING THE SAME", which is assigned to the assignee of the present invention and is hereby incorporated by reference.

Referring now to FIG. **8**, there is shown a core **100** embodied in accordance with a third embodiment of the present invention. The core **100** has substantially the same construction, is constructed in substantially the same manner and may be used in a transformer in substantially the same manner as the core **12**, except for the differences set forth below. Instead of having only one inner leg **22**, like the core **12**, the core **100** has three inner legs **22**. In addition, the core **100** has first and second outer legs **102**,**104** with rectangular cross-sections, instead of cruciform cross-sections, as in the core **12**. Also, the core **100** has upper and lower yokes **106**,**108**, each of which is comprised of a plurality of stacks of plates, instead of only a single stack, as in the core **12**. Further, the upper yoke **106** of the core **100** has three upper grooves **46***a,b,c* and the lower yoke **108** of the core **100** has three lower grooves **48***a,b,c*, instead of a single upper groove **46** and a single lower groove **48**, as in the core **12**. With the construction described above, the coil windings **80** are mounted to the three inner legs **22** of the core **100**, respectively.

The upper yoke **106** comprises a center stack **110** of plates **112** and first and second outer stacks **114**, **116** of plates **118**. Similarly, the lower yoke **108** comprises a center stack **120** of plates **122** and first and second outer stacks **124**,**126** of plates **130**. Each of the plates **112**,**122** is elongated and has opposing tined ends. Each of the plates **118**, **130** is trapezoidal in shape and has opposing ends mitered at oppositely-directed angles of about 45°. In the upper yoke **106**, an inner end of the first outer stack **114** cooperates with a first end of the center stack **110** to define the upper groove **46***a*, while an inner end of the second outer stack **116** cooperates with a second end of the center stack **110** to define the upper groove **46***c*. Similarly, in the lower yoke **108**, an inner end of the first outer stack **124** cooperates with a first end of the center stack **1 20** to define the lower groove **48***a*, while an inner end of the second outer stack **126** cooperates with a second end of the center stack **120** to define the lower groove **48***c*. The upper groove **46***b* is formed in the center stack **110**, and the lower groove **48***b* is formed in the center stack **120**.

In the upper yoke **106**, the first and second outer stacks **114**,**116** may simply abut the center stack **110**, i.e., form seams with the center stack **110**, or the plates **118** of the first and second outer stacks **114**,**116** may form multi-step lap joints with the plates **112** of the center stack **110**. Similarly, in the lower yoke **108**, the first and second outer stacks **124**, **126** may simply abut the center stack **120**, i.e., form seams with the center stack **120**, or the plates **130** of the first and second outer stacks **124**,**126** may form multi-step lap joints with the plates **122** of the center stack **120**.

A transformer core embodied in accordance with the present invention provide a number of benefits over conventional transformer cores. For example, providing the transformer core with legs having cruciform cross-sections increases the strength of the core and provides the legs with larger surface areas for supporting coil windings, while providing the transformer core with yokes having rectangular cross-sections simplifies the construction of the yokes (and, thus, the core) and reduces the amount of metal wasted in constructing the yokes (and, thus, the core).

While the invention has been shown and described with respect to particular embodiments thereof, those embodiments are for the purpose of illustration rather than limitation, and other variations and modifications of the specific embodiments herein described will be apparent to those skilled in the art, all within the intended spirit and scope of the invention. Accordingly, the invention is not to be limited in scope and effect to the specific embodiments herein described, nor in any other way that is inconsistent with the extent to which the progress in the art has been advanced by the invention.

What is claimed is:

1. A method of forming a transformer comprising:

(a.) providing a plurality of outer leg plates;

(b.) providing a plurality of inner leg plates, wherein not all of the inner leg plates have the same width;

(c.) providing a plurality of yoke plates, each of the yoke plates having a one-piece construction and an outer side and an inner side with a V-shaped notch formed therein, the V-shaped notch being located inwardly from the outer side, and wherein all of the yoke plates have the same width;

(d.) stacking the outer leg plates, the inner leg plates and the yoke plates to form a pair of outer legs, a yoke with a groove, and an inner leg having a first end disposed in the groove, wherein the outer legs comprise the outer leg plates, the inner leg comprises the inner leg plates and the yoke comprises the yoke plates, the groove extending in a stacking direction of the yoke and being formed by the V-shaped notches of the yoke plates, wherein the inner leg plates are stacked so as to provide the inner leg with a cruciform cross-section and the yoke plates are stacked so as to provide the yoke with a rectangular cross-section; and

(e.) mounting a coil winding to the inner leg.

2. The method of claim **1**, wherein the outer leg plates comprise first outer leg plates and second outer leg plates, wherein the outer legs comprise a first outer leg formed from the first outer leg plates and a second outer leg formed from the second outer leg plates, and wherein the step of stacking the outer leg plates, the inner leg plates and the yoke plates comprises:

(d1.) forming a core segment by:

forming joints between ends of a group of the yoke plates and ends of a group of the first outer leg plates;

forming joints between other ends of the group of the yoke plates and ends of a group of the second outer leg plates; and

positioning a group of the inner leg plates such that first ends of the inner leg plates are disposed in the V-shaped notches of the group of the yoke plates; and

(d2.) repeating the steps of stacking (d1.) to form a plurality of the core segments and thereby form the yoke, the inner leg and the first and second outer legs.

3. The method of claim **2**, wherein the forming of the core segments is performed such that the joints between the yoke and the first and second outer legs are multi-step lap joints.

4. The method of claim **2**, wherein the inner leg comprises a plurality of sections of the inner leg plates, each section having a different width, and wherein in each of the sections, the inner leg plates have the same width; and

wherein each of the sections of the inner leg plates comprises one or more of the groups of the inner leg plates.

5. The method of claim **2**, wherein the yoke plates are first yoke plates and the yoke is a first yoke, and wherein the method further comprises:

providing a plurality of second yoke plates, each of the second yoke plates having an outer side and an inner side with a notch formed therein, the notch being located inwardly from the outer side, and wherein all of the second yoke plates have the same width; and

stacking the second yoke plates to form a second yoke with a groove extending in a stacking direction of the second yoke, the groove being formed by the notches of the second yoke plates, the second yoke plates being stacked such that a second end of the inner leg is disposed in the groove of the second yoke.

6. The method of claim **5**, wherein the second yoke has a rectangular cross-section; and

wherein the mounting of the coil winding to the inner leg is performed before the stacking of the second yoke plates.

7. The method of claim **2**, wherein the first ends of the inner leg plates are tined, and wherein in each of the groups of the inner leg plates, the first ends are vertically offset such that the first ends are located successively farther downward in a stacking direction of the inner leg.

8. The method of claim **7**, wherein in each of the groups of the yoke plates, the V-shaped notches are successively deeper in the stacking direction of the yoke so as to accommodate the vertically offset first ends of the inner leg plates in the corresponding group of the inner leg plates, whereby the first ends of the inner legs plates form vertical multi-step lap joints with the yoke plates.

9. The method of claim **1**, wherein the stacking of the outer leg plates, the inner leg plates and the yoke plates is performed in a vertical direction.

10. The method of claim **9**, further comprising clamping the yoke between a pair of supports;

disposing bands around the inner leg and the outer legs; and

moving the outer legs, the yoke and the inner leg so that the outer legs and the inner leg extend vertically; and

wherein the coil winding is mounted to the inner leg when the inner leg is extending vertically.

11. The method of claim **1**, wherein each of the outer legs comprises a plurality of sections of the outer leg plates, each section having a different width, and wherein in each of the sections, the outer leg plates have the same width; and

wherein each of the outer legs has the cruciform cross-section.

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